REINHOLD ENVIRONMENTAL Ltd.

2014 APC Round Table & Expo Presentation

July 14-15, 2014, in Louisville, KY / Hosted by LG&E/KU

Economic Viability in the Eye of the Storm
Preserving Coal-Fired Generation Asset Life

Peter Spinney
NeuCo, Inc.

Reinhold APC/PCUC Conference
Louisville, Kentucky
July 14th,2014

NeuCo
The Optimization Standard™

ProcessLink®

Key Challenges

- Unprecedented regulatory uncertainty
  - CSAPR Implementation
  - Federal CO_2 regulation
  - MACT Enforcement
- Traditional and new sources of market volatility
  - Demand uncertainty (fighting the last war)
  - Fuel and allowance price volatility
  - Technological uncertainties
- All add to challenges bringing new capacity on-line
- CCCTs and renewables force new operating profiles
- Aging assets operating well beyond design life
- Graying work-force and skills shortage

Do more with less and manage the risks!

NeuCo
The Optimization Standard™

Current and Pending Air Emission Regulations

- Acid Rain Program
- National Ambient Air Quality Standards (NAAQS) for SO_2, PM, and ozone
- New Source Review
- New Source Performance Standards
- The Regional Haze Rule
- Cross State Air Pollution Rule
- Clean Air Interstate Rule (while CSAPR being updated)
- Expanded Ozone Transport Corridor
- Greenhouse Gas Rule for New Sources
- Greenhouse Gas Standards for Existing Plants
- MATS

Recent Developments for NOx Regulations

- CSAPR vacatur and reinstatement
  - Implementation timeline
  - New state NOx budgets
  - Allowance market dynamics
- Aggressive NSR enforcement
  - 70 plants currently in litigation
- New PM 2.5 limits
- Stricter 8-hour ground-level ozone limits
- Regional Haze/BART filings

Cross-State Air Pollution Rule (CSAPR)

- Establishes four interstate trading programs for addressing Clean Air Act National Ambient Air Quality Standards (NAAQS)
- Particulates (PM 2.5)
  - SO_2 Program
    - Two (12-month annual) programs based on stringency of reductions needed to eliminate their significant contribution
  - NOx Annual Program (All 12 months of the year)
- 8-Hour Ground Level Ozone
  - NOx Ozone Season (5 months May through September)
- 28 states must reduce power plant emissions that contribute to ozone and PM2.5 in other states

Mercury and Air Toxics Standard (MATS)

- Requires all plants to reduce hazardous air pollutants and increase efficiency to mitigate unmeasured air toxins
  - Quantitative HAPS limits for Hg, acid gases, toxic metals and particulates
  - Requires boiler tuning & performance measurement every 3 years starting in 2015
- Generators must invest in HAPS mitigation to control Hg, acid gases, toxic metals, and fine particulates
  - ACI/DSI, baghouses, FGD, SCR are complicating strategic operational, compliance and financial decisions
  - Total plant operations face big leaps in complexity and severity of consequences
- Work Practices impose an added level of new risks
  - Poorly defined tuning, testing, & record retention requirements for coal boilers by April 2015 and every 3 years thereafter
  - Remedies (repair/replace/pay fine) are poorly defined
  - Unique 1-year deferral, 4-year cycle and simplified testing standard offered to generators using a neural network to optimize for NOx and CO

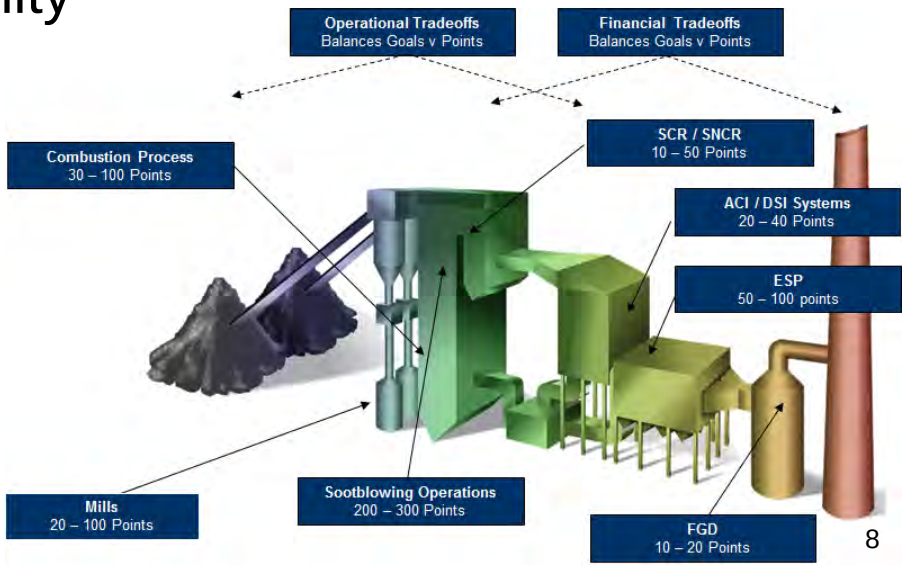
MATS Work Practices: EPA defines Optimization

- Optimizing for NOx and CO
  - Burners
  - OFA
  - Concentric firing system improvements
  - Neural network or combustion efficiency software
  - Control system calibrations
  - Adjusting combustion zone temperature profiles
  - Add-on controls such as SCR / SNCR
- EPA gives neural optimization for NOx and CO special status
  - Generators using a neural network to optimize NOx and CO in normal operations:
    - Can defer initial testing/tuning until April 2016
    - Perform subsequent testing on a four year rather than a three year basis
    - Fulfill testing requirements by reporting average CEMS data with and without the optimizer in service

NeuCo
The Optimization Standard™

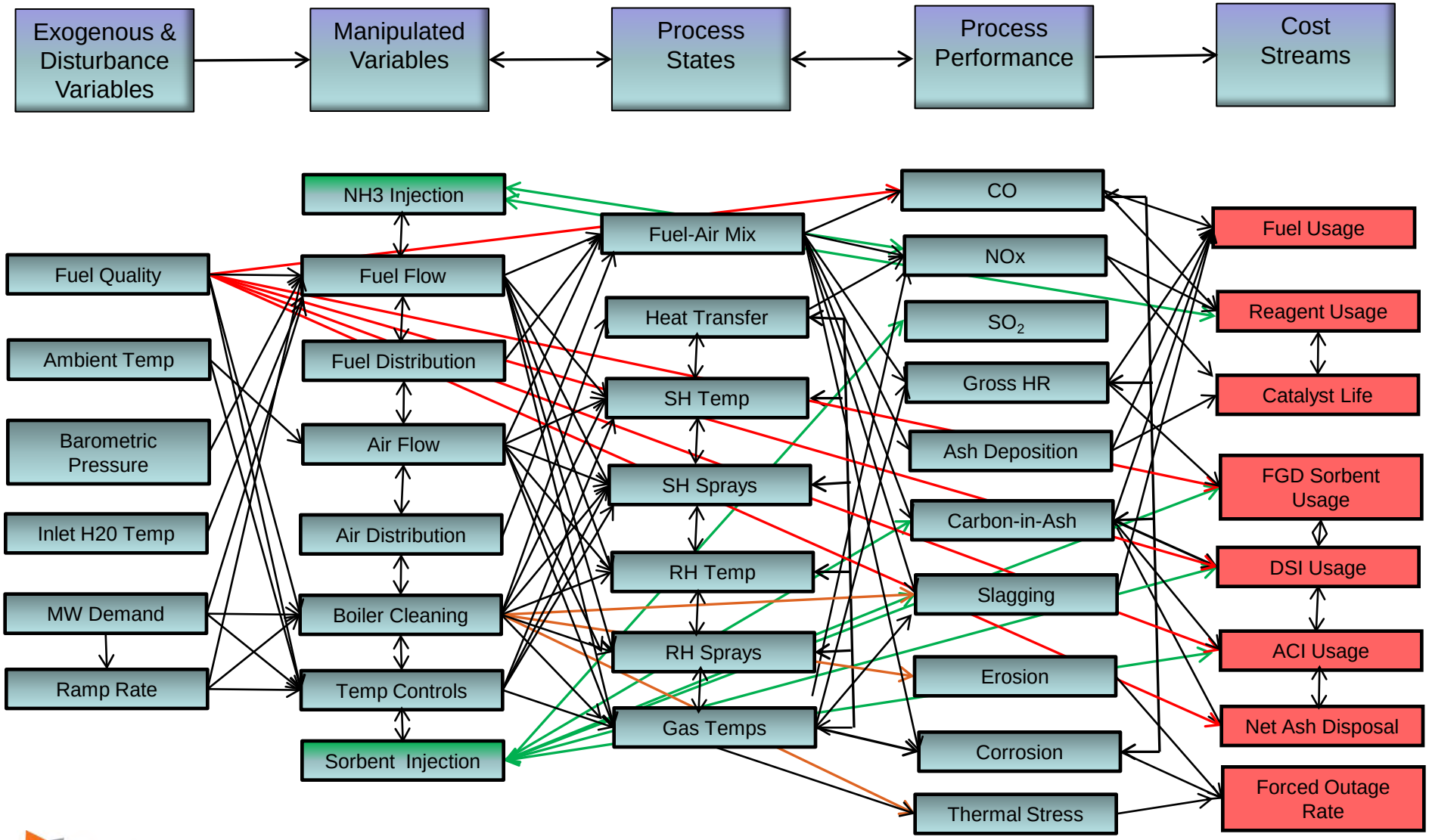
Bunker to Stack Optimization Opportunity

- Generating units need to operate as one system
  - In varying conditions
  - With distinct, sometimes conflicting objectives
  - In a highly inter-related, interdependent environment
- Examples
  - Low NOx – Where? In boiler, out of SCR? At what load?
  - Low Hg – How? Through DSI / ACI, with carbon in ash?
  - High SOx removal - With what parasitic loss? What pH?
- Back-end optimization opportunity
  - Account for multiple goals
  - Enhance multiple processes
  - Multi-pollutant tradeoffs
  - Find sweet spots



NeuCo
The Optimization Standard™

Boiler & Back-End Process Causality Chain



NeuCo
The Optimization Standard™

Integration of Emissions, Efficiency & Availability Silos

- Emissions, efficiency, and availability used to be addressed by different “silos” within power generation organizations
- Efficiency efforts often took back seat to emissions
  - Regulatory “pass-through” clauses
- Fuel costs often handled fleet-wide
- Multi-pollutant challenges have availability implications
- Reagent costs for NOx create large new “non-fuel” O&M cost

Bottom Line: Must integrate management of reliability, emissions, fuel, reagent costs and tradeoffs between them

NeuCo
The Optimization Standard™

Asset Optimization Fundamentals

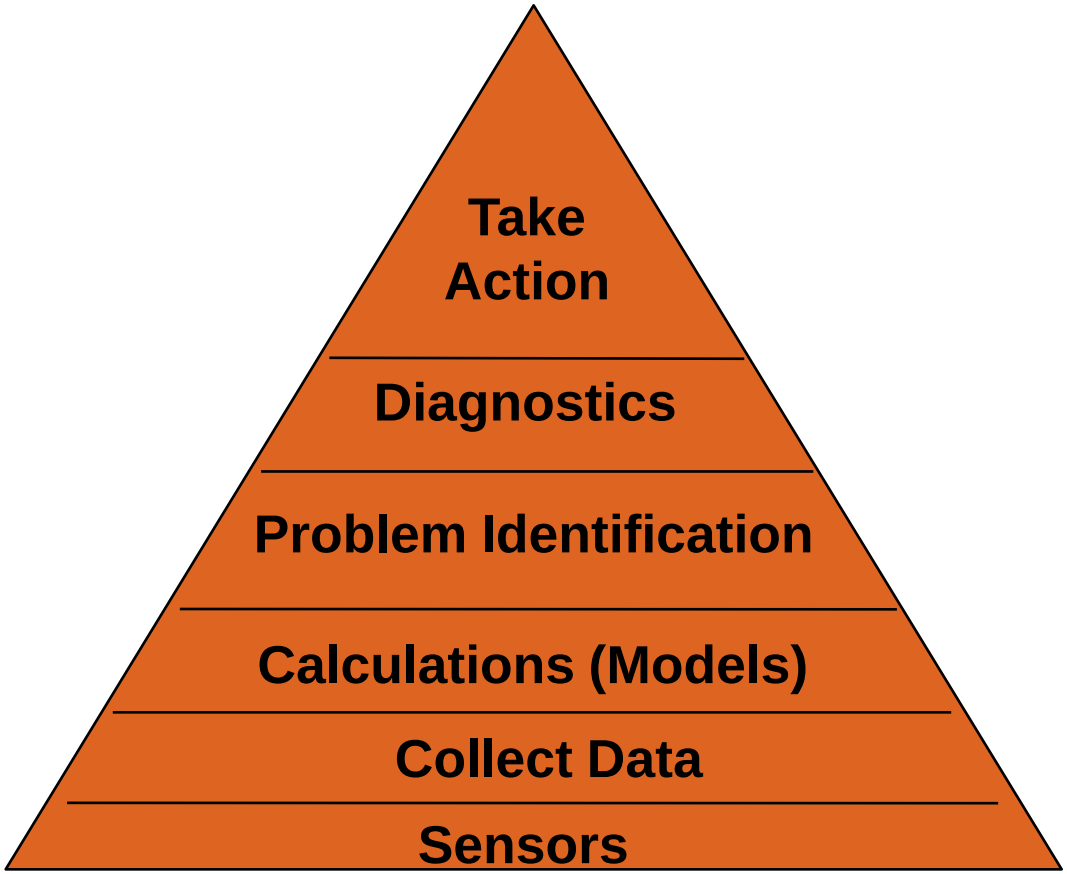
- Caring for and making best sustained use of physical plant, infrastructure and associated facilities
- Reconciling the conflicting objectives of near-term profitability with long-term return on investment
- Continuously striving to find the organizational strategies, technology investment, operational practices and maintenance approaches that maximize asset value
- A new framework is rapidly emerging that embodies these principles: PAS-55
  - *Systematic & coordinated practices for optimally managing physical assets and their associated performance, risks and expenditures over their lifecycles for the purpose of achieving an organization's overall strategic plan*
- While developed in the UK, PAS-55 is rapidly being deployed globally, and is likely to be adopted internationally as ISO-55000

NeuCo
The Optimization Standard™

Taking a Holistic Platform Approach

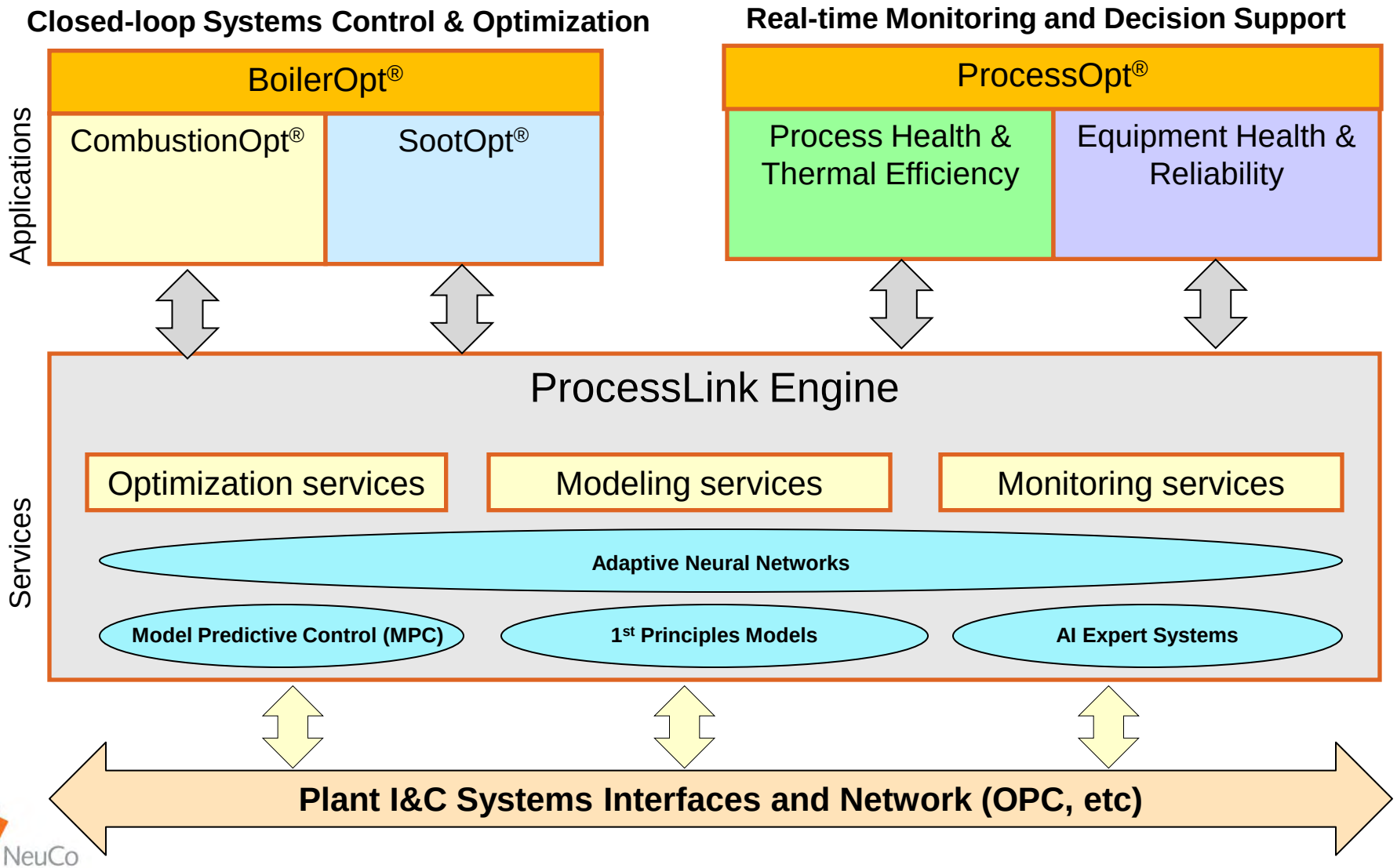
- ProcessLink is the technology platform upon which all NeuCo Optimizers are built:
  - Solves problems too large / complex for people alone to address or automates problem solving so that people can to focus on other issues
  - Employs multiple modeling and optimization techniques to provide best hybrid asset optimization solutions
  - Integrates disparate data sources and knowledge, enabling objective-driven performance across units, plants or an entire fleet
  - Integrated modeling and optimization engine relates process behavior to global objectives
  - Supports optimizer integration and action coordination
  - Process behavior and equipment health issues surfaced though comprehensive alerts
  - Flexible GUIs, portals, and automated reporting

From Sensors to Optimal Action



NeuCo
The Optimization Standard™

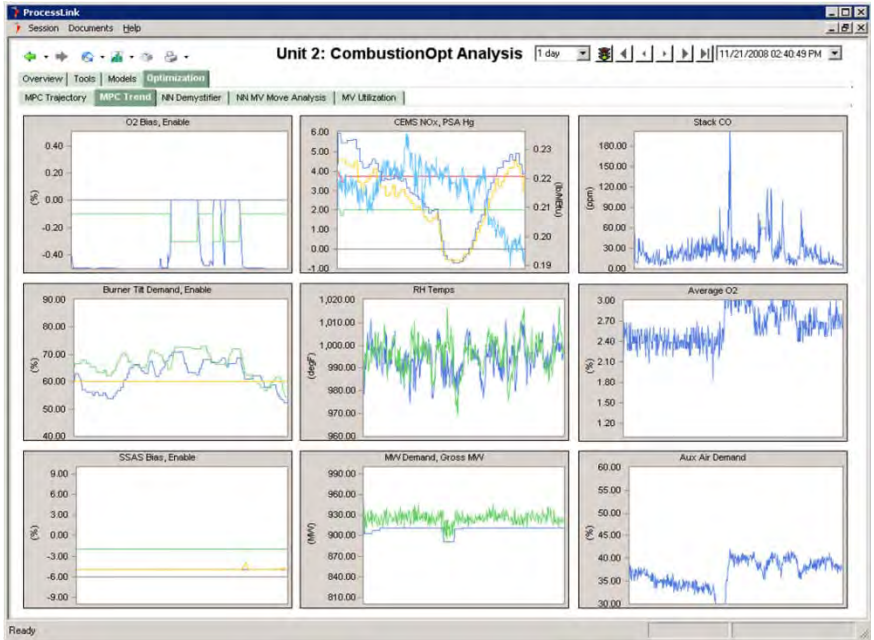
ProcessLink - Holistic Platform for Evolving Industry Needs



NeuCo
The Optimization Standard™

Combustion Optimization

- Results achieved through optimal mixing of fuel and air through MPC, adaptive neural networks and condition-based rules
  - NOx reductions of 10-15%
  - Boiler efficiency increase of 0.5% - 1.5%
  - CO controlled to desired limit
  - Better ramping and load-following performance
  - Reduced opacity excursions
  - Better control of LOI
  - Better adherence to fan and
  - Improved situational awareness process insight
  - Avoided tail-chasing behavior



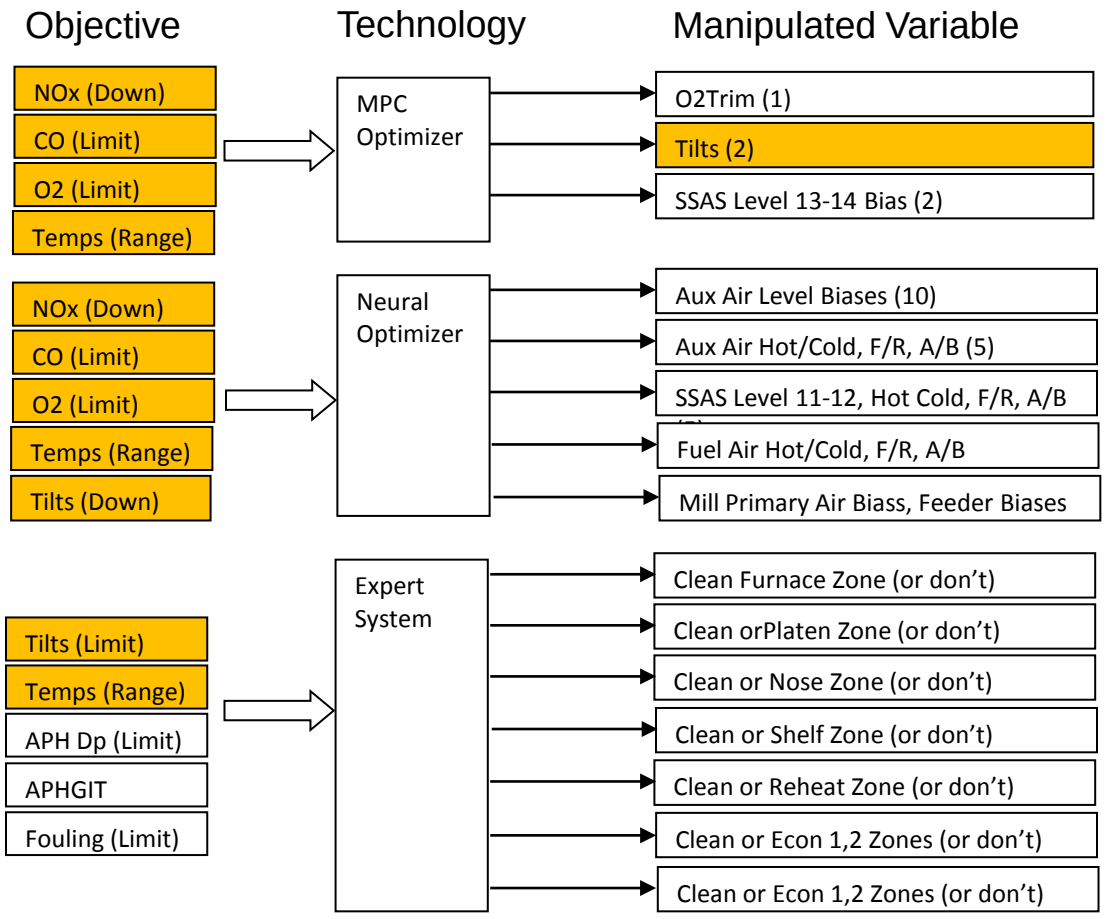
NeuCo
The Optimization Standard™

Boiler Cleanliness Optimization

- Real-time closed-loop optimization of boiler cleaning equipment using expert rules, thermal calculations and neural networks
  - Reduced and more tightly controlled APH temperatures
  - Improved SH and RH steam temperature control
  - Reduced attemperation sprays
  - Heat rate reduction of 0.75% - 1.50%
  - Incremental NOx reduction of 2.5% - 5%
  - Avoided opacity excursions
  - Reduced blowing of 10% - 35%
  - Avoided thermal stress from blowing clean surfaces
  - Fewer tube-leak failures
  - Improved situational awareness and process insight

NeuCo
The Optimization Standard™

Pulling the Key Boiler Processes Together

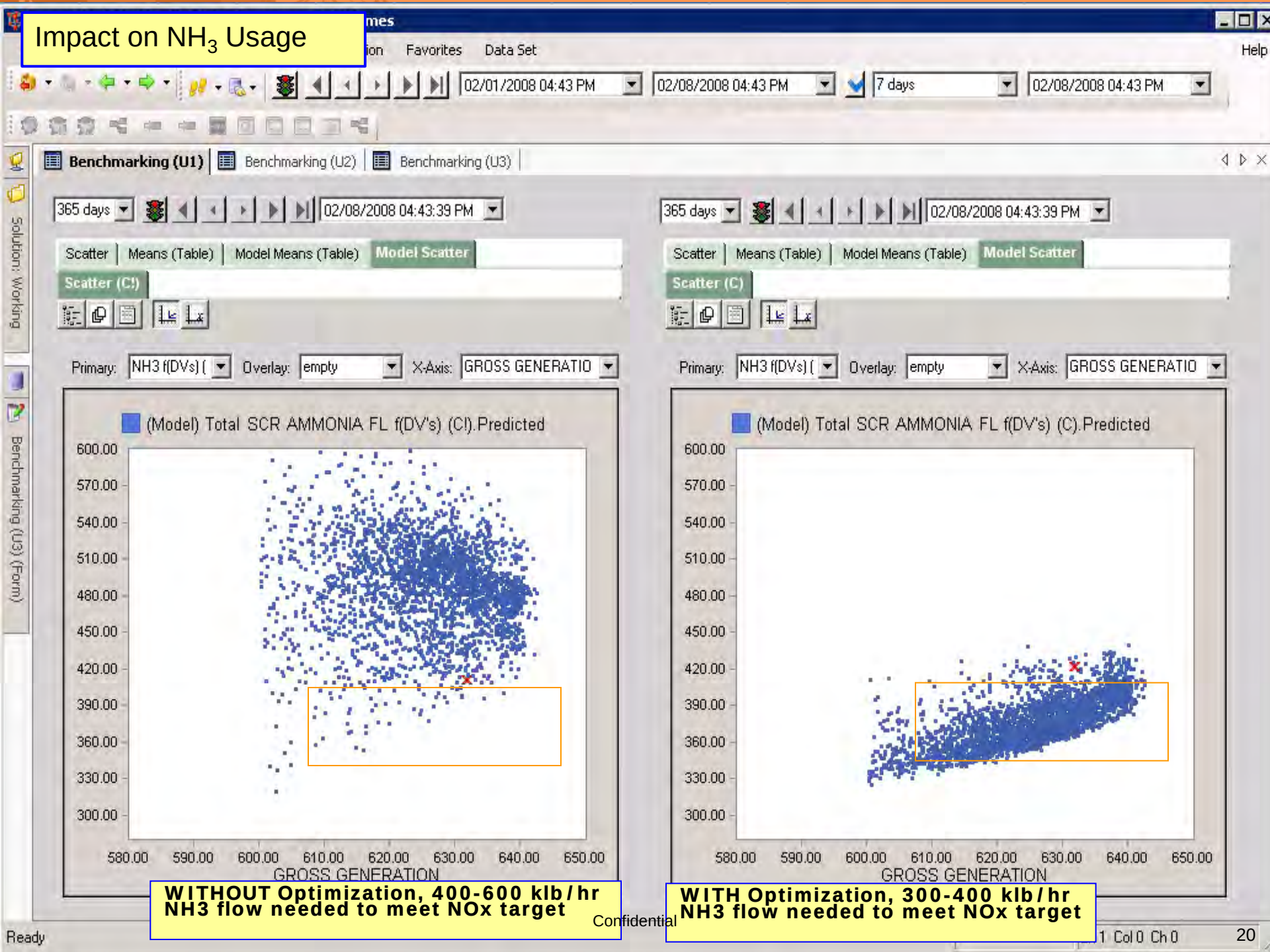


NeuCo
The Optimization Standard™

Downstream Optimization Impact on SCR/SNCR

- SCR/SNCR Systems & Optimization
  - Reduce Reagent Usage
  - Increase NOx to avoid poisoning catalyst
  - Lengthen Maintenance Intervals
  - Avoid Ammonia Slip
  - Reduce risk of Ammonium Bisulfate & Sulfur Trioxide deposits
  - Control “Blue-Plume” Opacity Excursions
  - Tighter, condition-based gas temperature control
  - Better manage system interactions

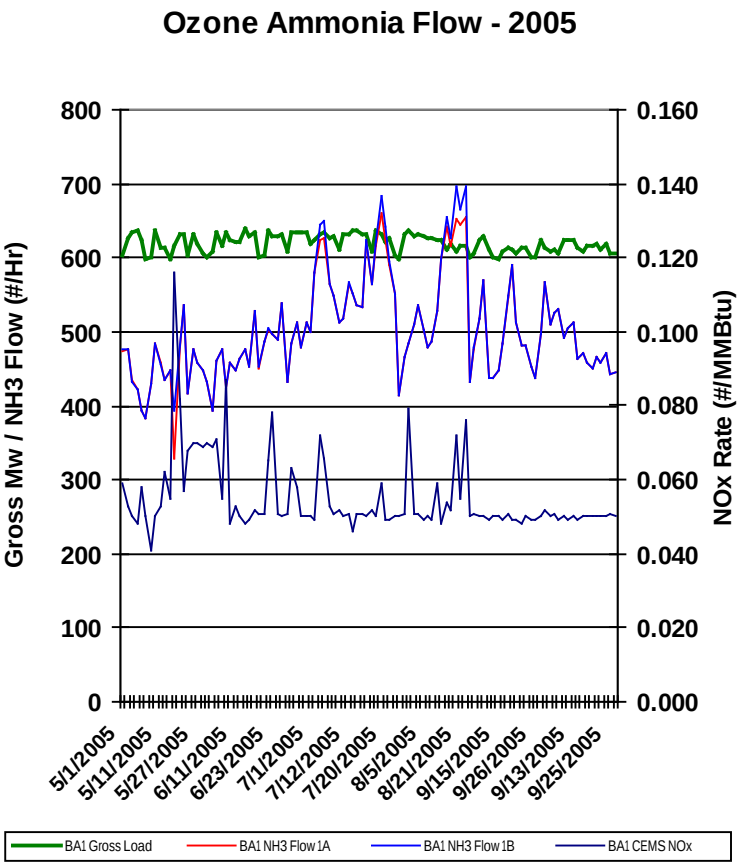
Impact on NH_3 Usage

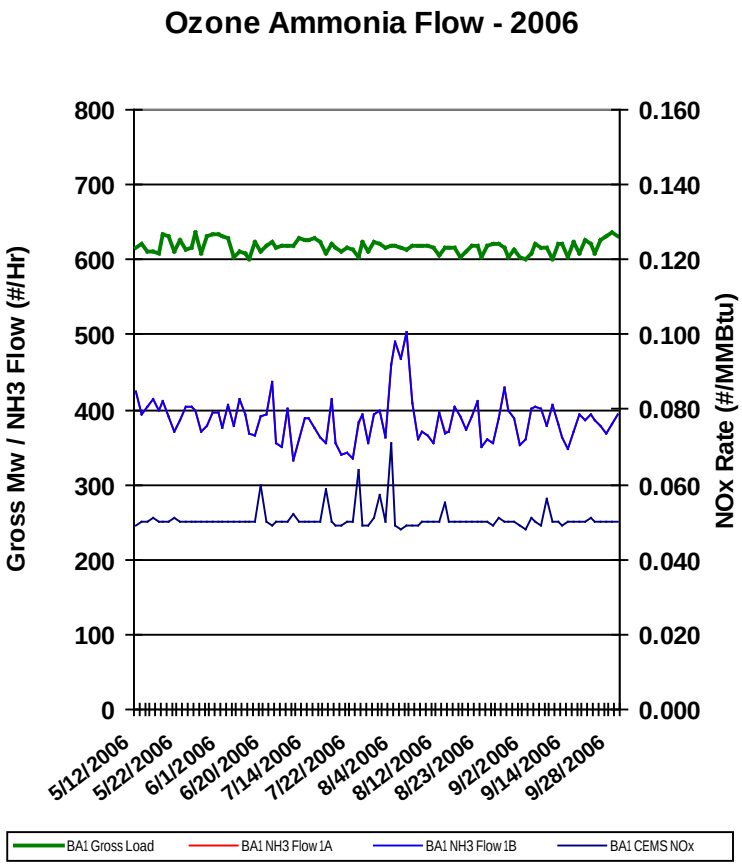


WITHOUT Optimization, 400-600 klb/hr NH3 flow needed to meet NOx target

WITH Optimization, 300-400 klb/hr NH3 flow needed to meet NOx target

Combustion Optimization Ammonia Reduction





NeuCo
The Optimization Standard™

New Opportunities for Back-end Optimization

- SCR systems
  - NOx removal efficiency
  - NH_3 flow minimization
  - Low load operation
  - SO_2 to SO_3 conversion
- FGD systems
  - SO_2 removal efficiency
  - Pumps in service
  - Limestone usage
  - pH control
  - Vessel level
- ESP
  - Voltage levels
  - Rapper location and frequency
- DSI / ACI
  - Balance with carbon in ash
  - Injection rates

NeuCo
The Optimization Standard™

NeuCo/NRG Texas CCPI II Project

Project Title: Mercury Specie and Multi-Pollutant Control

Project Abstract: "NeuCo will demonstrate on a large utility coal fired boiler (NRG Texas Limestone Unit 2) the ability to affect and optimize mercury speciation and multi-pollutant control using non-intrusive advanced sensor and optimization technologies with no impact to saleable products and improvement in heat rate…"

Contract Award Date: April 19, 2006

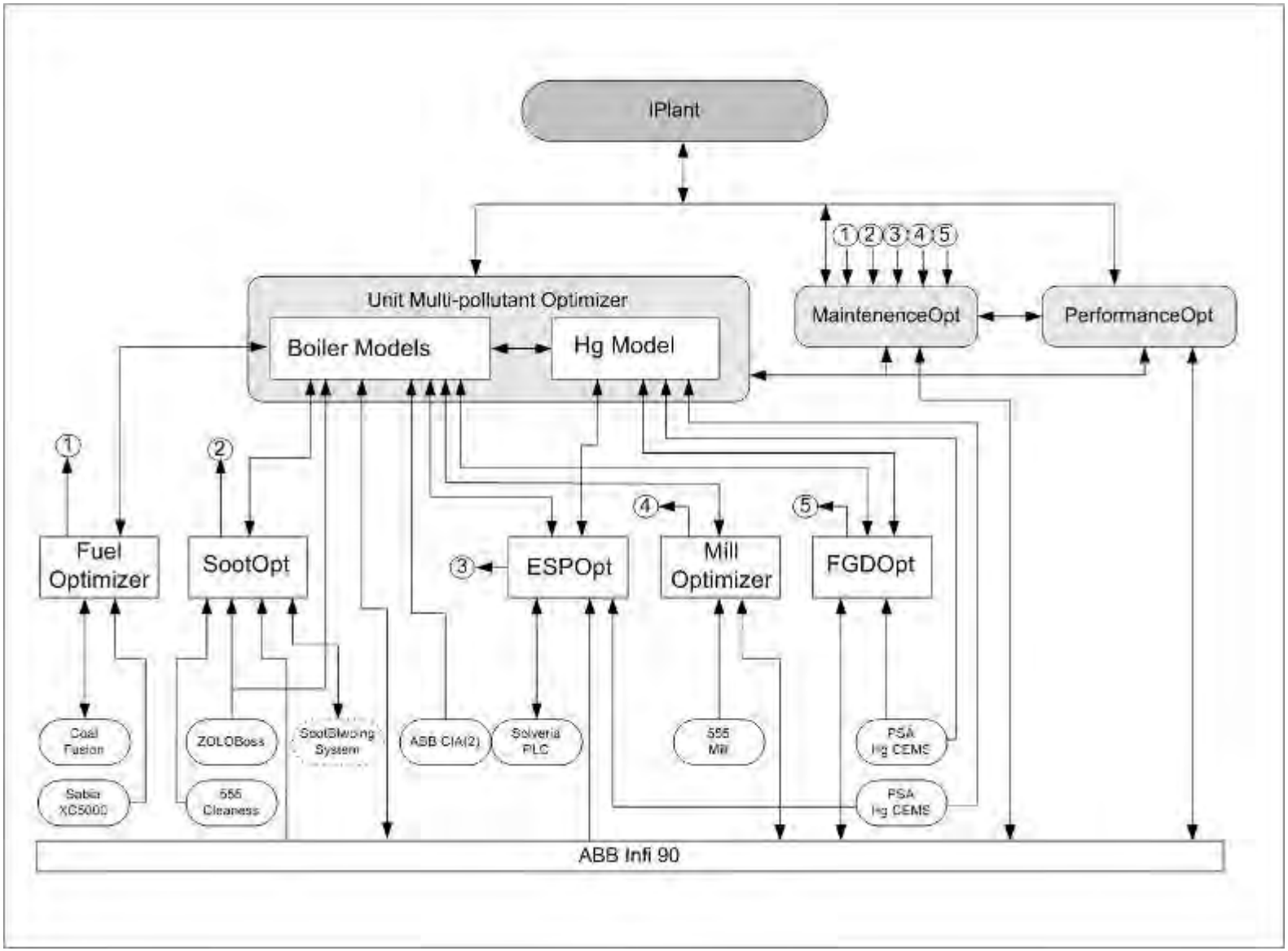
Contract Phases:

Phase I: Installation of advanced sensors
Phase II: Installation of optimization technology
Phase III: Demonstration of system

Project Successfully Completed: September, 2010

NeuCo
The Optimization Standard™

Optimization Architecture for Project



NeuCo
The Optimization Standard™

Anomaly Detection & Alerting for Equipment Health and Process Performance

- Optimization helps improve availability and efficiency by:
  - Using predictive analytics to identify potential equipment health and process performance issues
  - Providing early warnings for impending failures and degradation
  - Minimizing unnecessary outages
  - Sponsoring better use of planned down-time
  - Maximizing efficiency
  - Proactively managing emissions compliance
  - Avoiding deleterious excursions

NeuCo
The Optimization Standard™

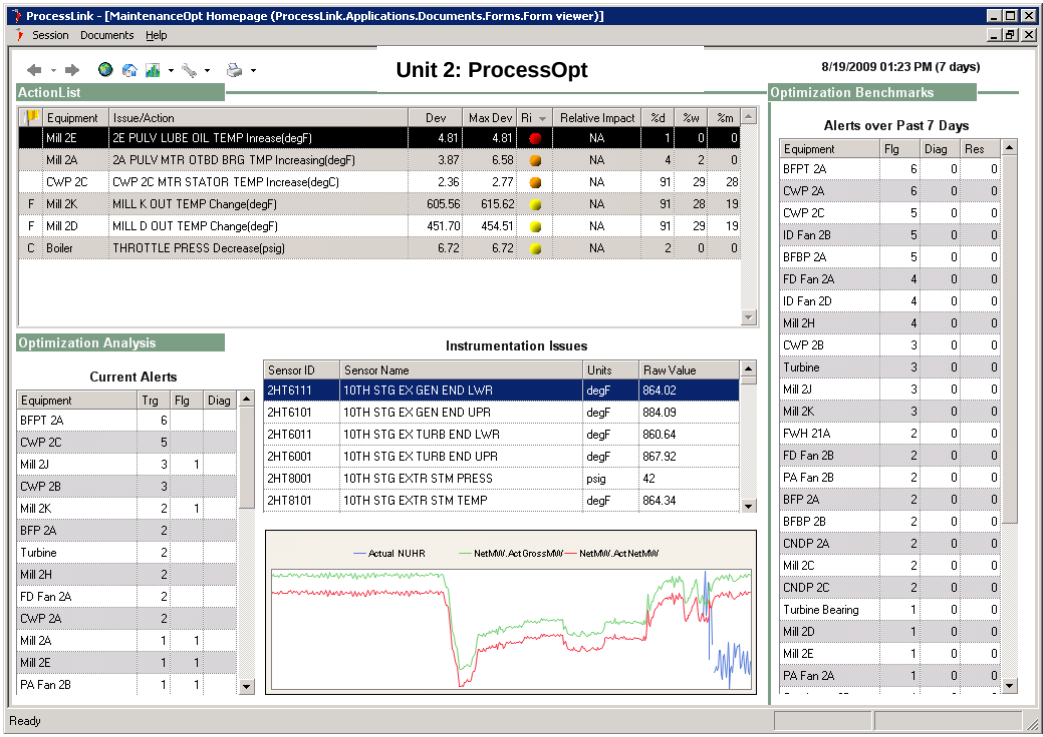
Real-Term Anomaly Detection & Alerting

- What it does:

  Automatically alerts users to symptoms of potential equipment health issues (efficiency, capacity or reliability based) and allows quick easy drill down to uncover actionable responses to diagnose and remedy the underlying problems.

- Using:
  - Neural Networks
  - Expert Rules
  - Other Optimizer Alerts

- To Improve:
  - Unit up-time
  - Efficiency
  - Speed of issue resolution



NeuCo
The Optimization Standard™

Some Examples of Potential Problems

The types of problems that can be detected are dependent upon the type of equipment. For example, for air heaters, the following provides a list of potential problems that may be identified:

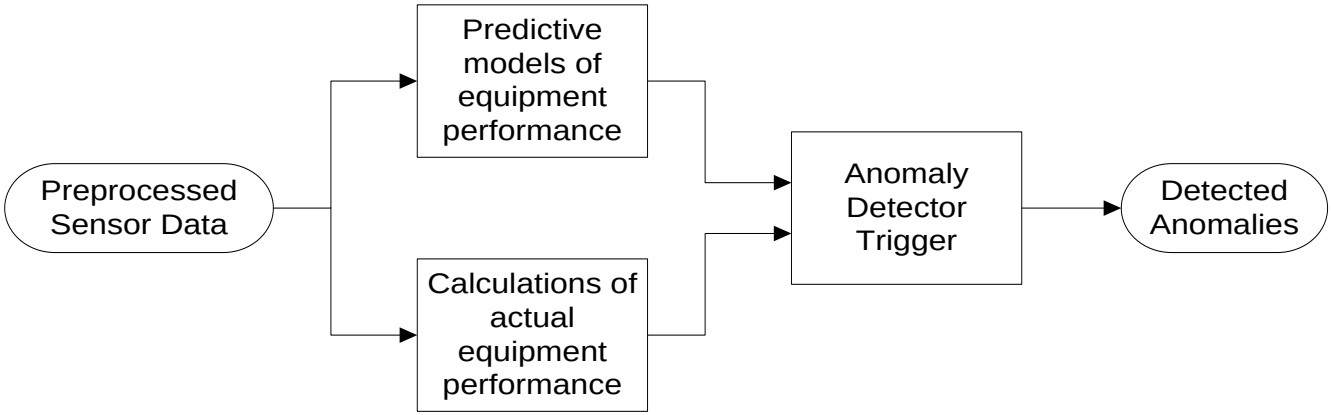
- Inaccurate leakage calculation due to stratification or instrument error
- Basket damage
- Ash or salt plugging
- Bearing inadequate oil cooling
- Shaft misalignment
- Bearing failure

Indicators of Potential Problems

The following process values associated with an air heater are monitored as part of an early warning system:

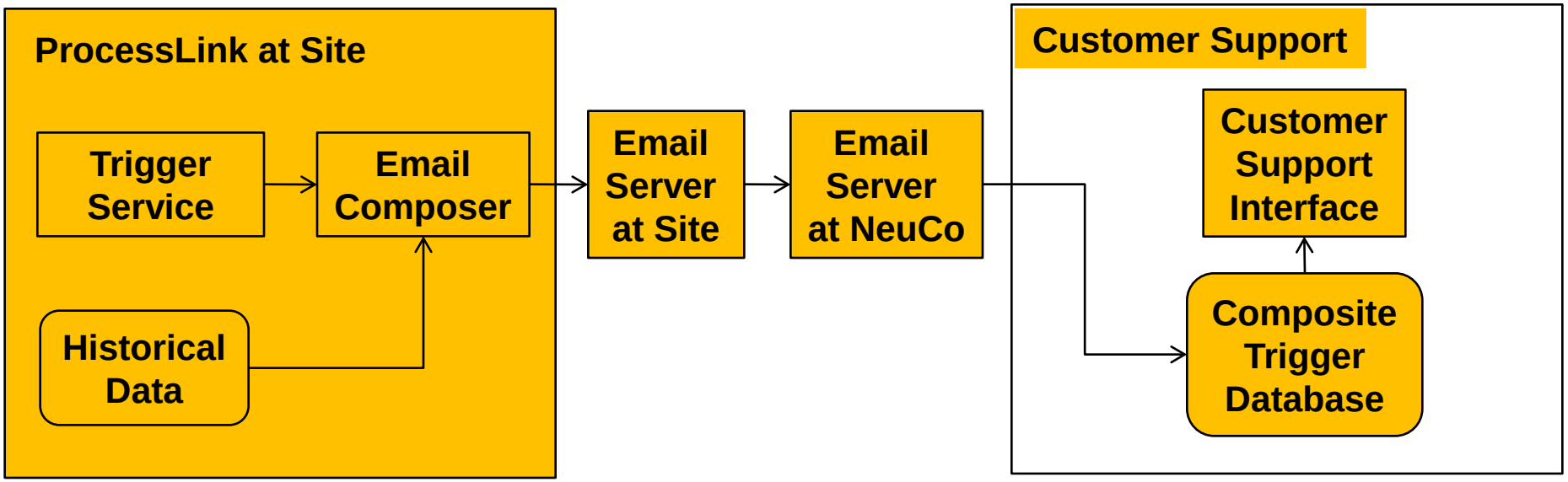
- High AH air or gas side pressure drop
- High AH cold end average temperature
- Low AH cold end average temperature
- Air Heater leakage increasing
- Increasing APH coil differential pressure
- Bearing temperature increasing

Problem Identification



- Model is used to predict equipment performance
- Model output is compared to actual performance
- If difference is larger than a threshold, an anomaly is detected
- Trigger fires, problem recorded, alert sent to relevant users

Automated Alerts Management

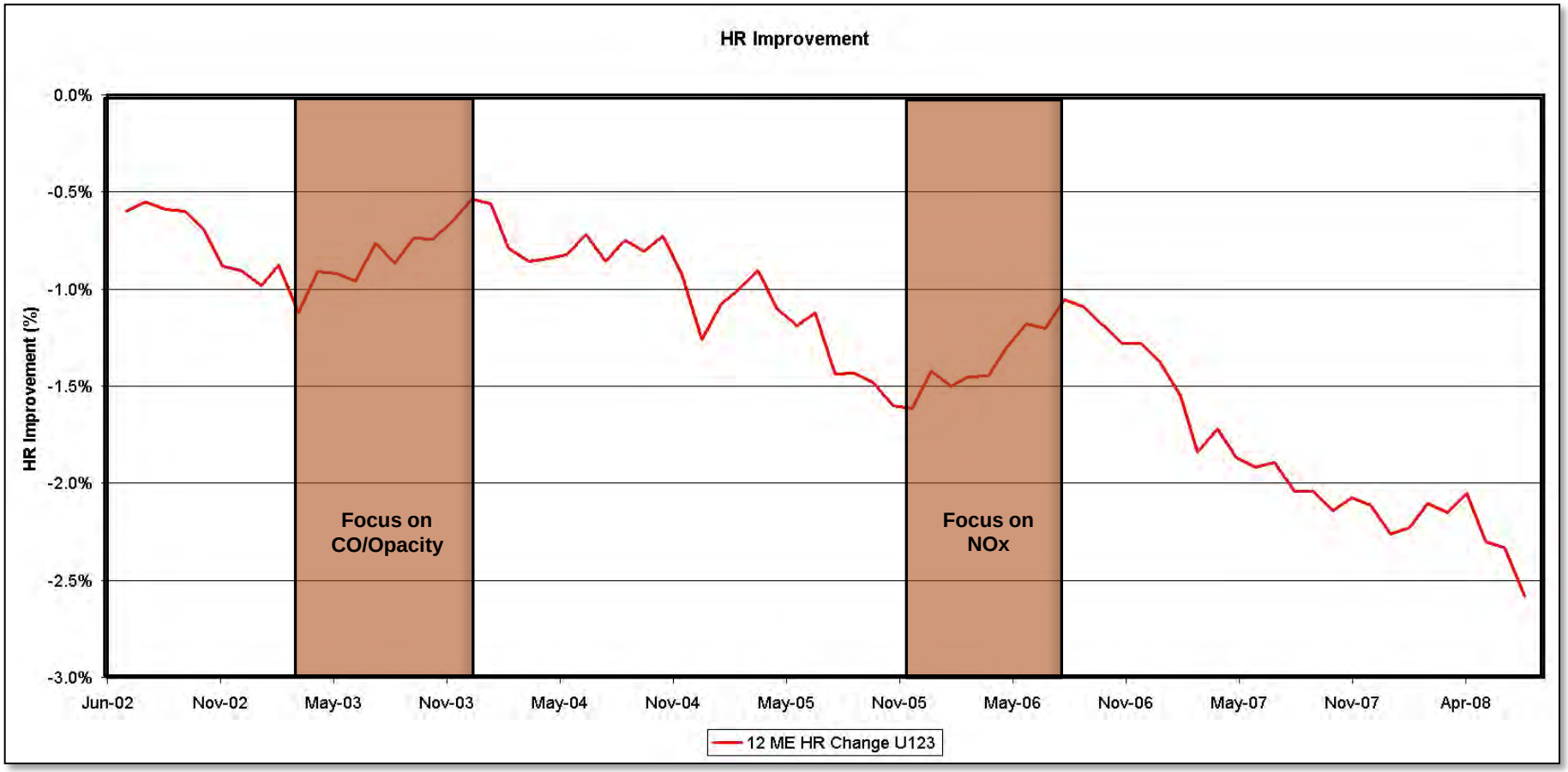


NeuCo
The Optimization Standard™

APS Four Corners Case Study

- Initial success with CombustionOpt at Unit 3 led subsequently to deployment on Units 1 and 2
  - All older front-fired 170-200 MW pulverized coal boilers
- Success on Units 1-3 led to adding Units 4 and 5
- Initial Objectives: HR & Opacity, NOx added later
- Ten years of benefits led to widespread roll-out of new optimization products
  - SootOpt, M'Opt, P'Opt at all five Four Corners Units
  - C'Opt, SootOpt, P'Opt at all three APS-owned Cholla units
- Also populating centralized fleet monitoring center

APS Four Corners Heat Rate Over 7 Years



NeuCo
The Optimization Standard™

Two Example ProcessOpt Catches

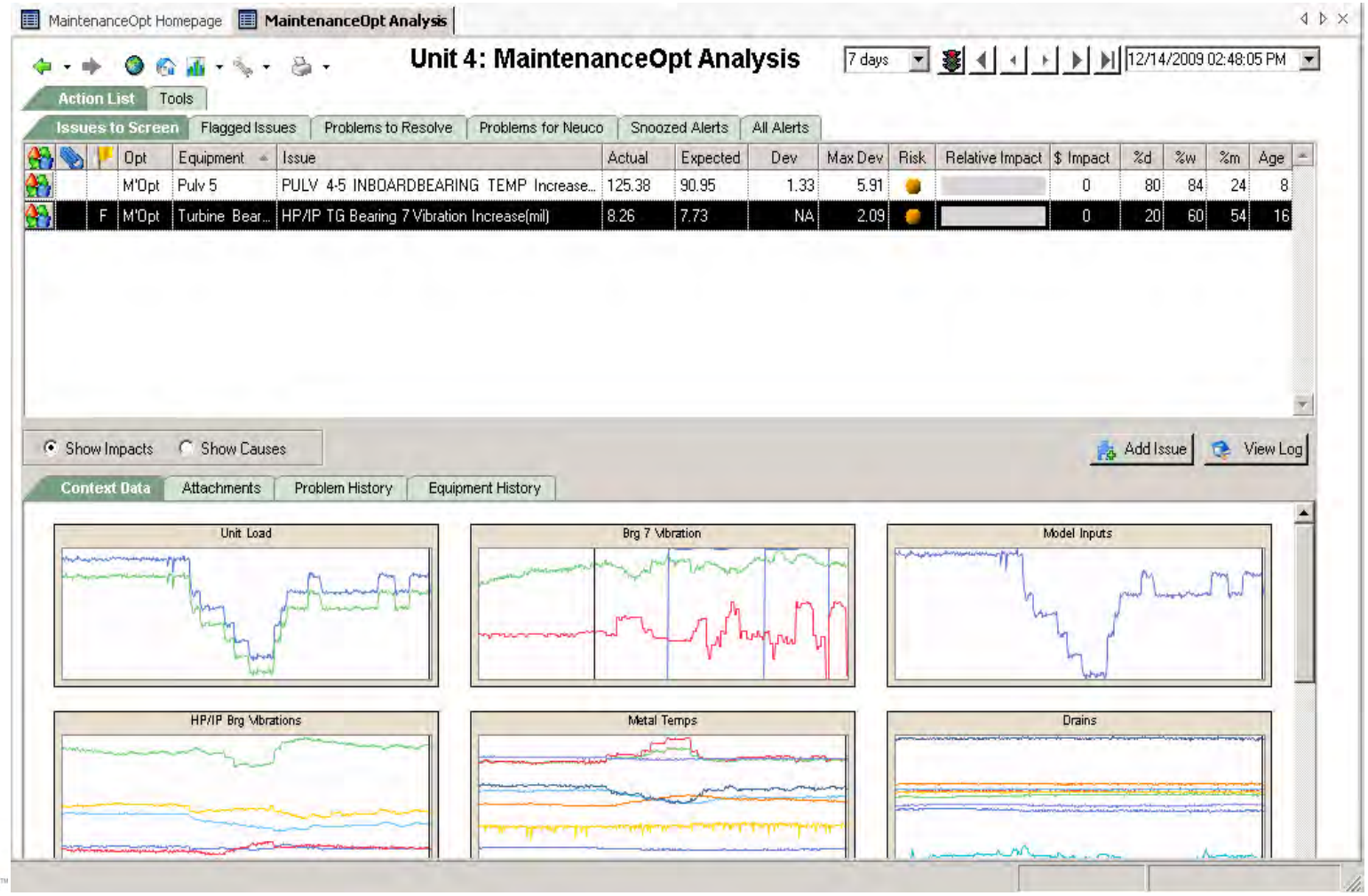
- Turbine bearing vibration problem
- Air evacuation problem on a condenser

Example 1: Turbine Bearing Vibration

- **Unit:** Four Corners Unit 4, 800 MW
- **Usage:** Routine checks of the unit are made daily
- **Incident:** During a routine check, it was observed that a turbine vibration is increasing. This problem is being monitored daily to verify that it does not suddenly increase
- **Fix:** Turbine is due for an overall at the next outage. Problem fixed at the outage. In the interim, plant and NeuCo monitored vibration to make sure that it does not suddenly increase.

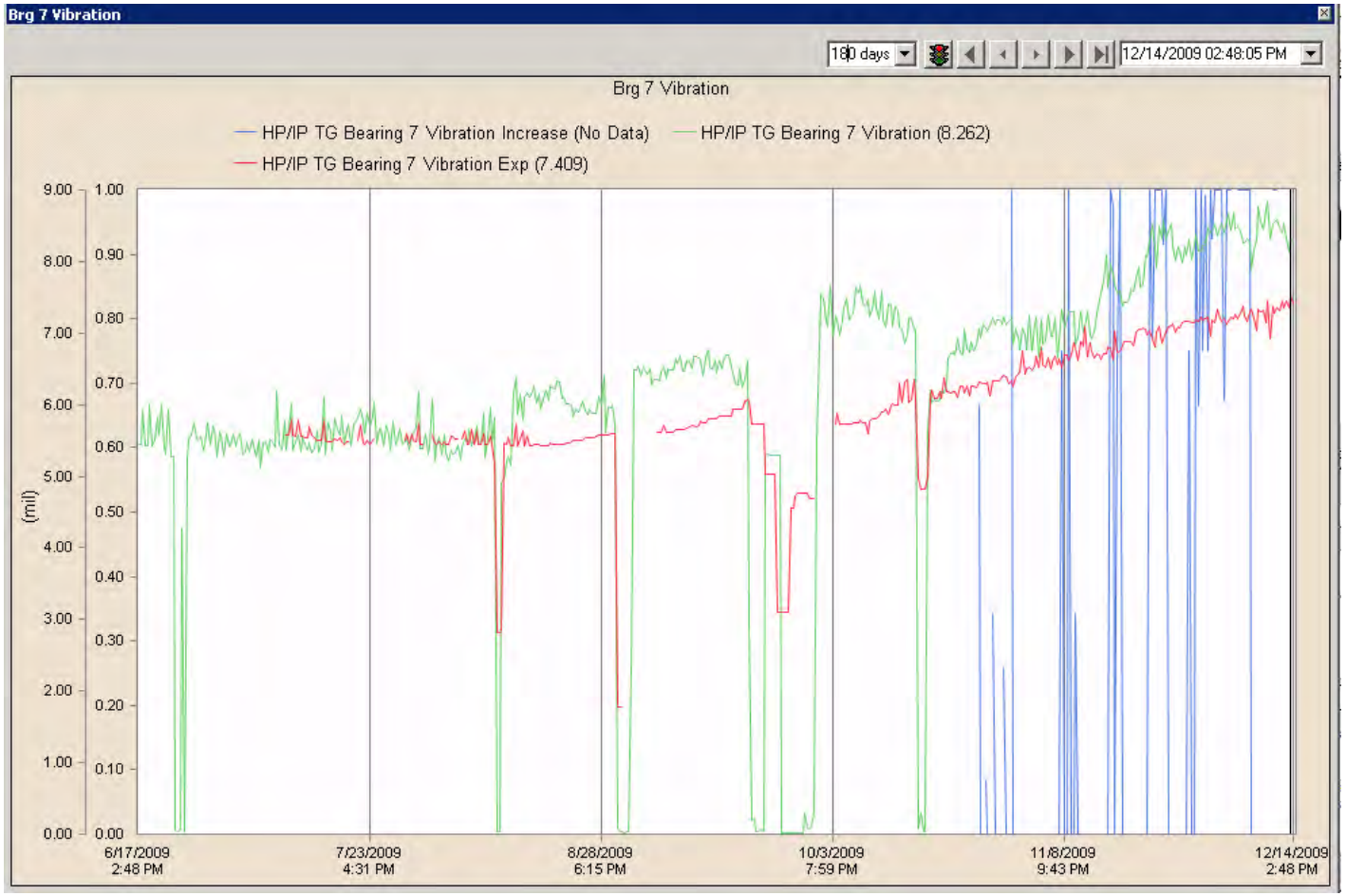
Vibration Alert

- Vibration on bearing #7 has triggered. Note that alert has been triggering >50% of the time over the past week and month.



Increasing Vibration

- Turbine bearing vibration increasing for past month (green). Neural model adapting to the change but not as fast as vibration increase (blue).



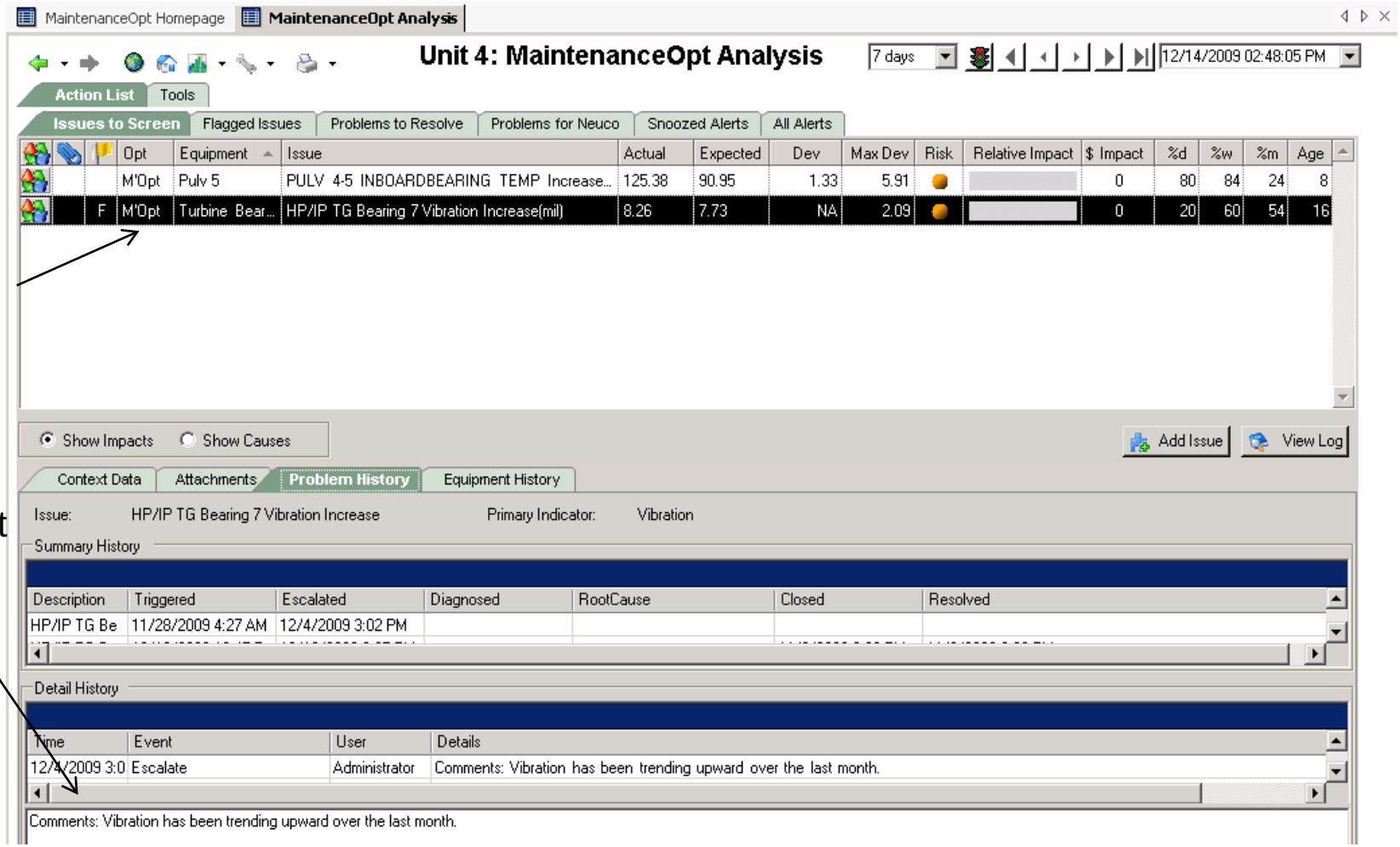
NeuCo
The Optimization Standard™

Monitoring the Problem

- User has flagged problem so that it stays on the *Issues to Screen* tab. The user also entered a comment. Monitoring will continue up to the outage.

Flagged item

User Comment



Example 2: Condenser Problem

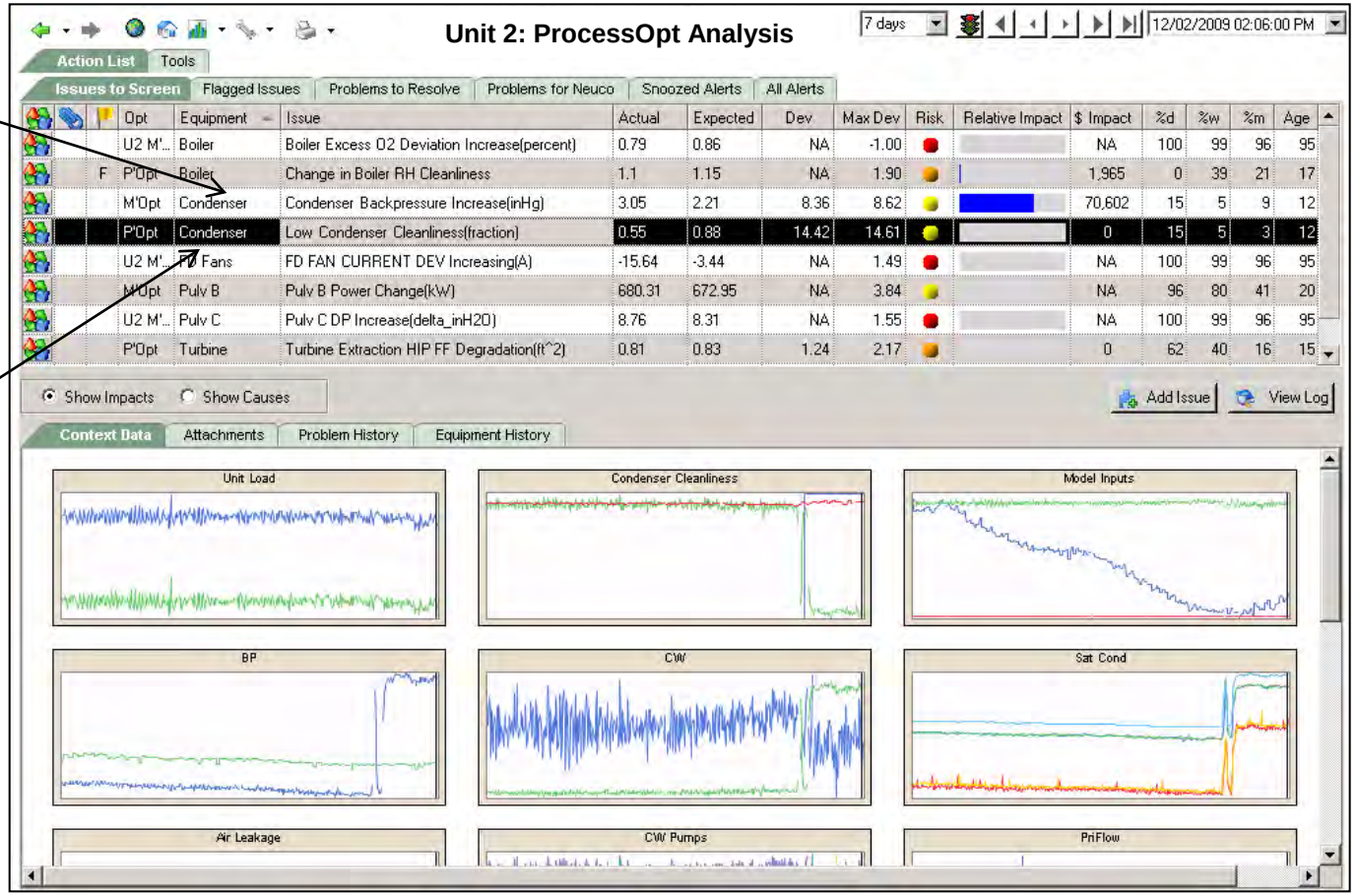
- **Unit:** Four Corner Unit 2, 190 MW
- **Usage:** During a check of PerformanceOpt and MaintenanceOpt by NeuCo, we noticed a large change in condenser performance. Plant was notified via email of the problem
- **Incident:** During routine maintenance on the condenser, the maintenance crew had inadvertently disconnect both vacuum pumps causing a large increase in backpressure
- **Fix:** The maintenance crew was notified of the problem and then properly connected a vacuum pump. The performance returned back to normal

Two Triggers Corroborate Problem

- Routine review of triggers show alerts on condenser backpressure and cleanliness have triggered. Backpressure at 3.05 when expected to be 2.2, and cleanliness at 0.55 when expected at 0.88.

Backpressure Alert

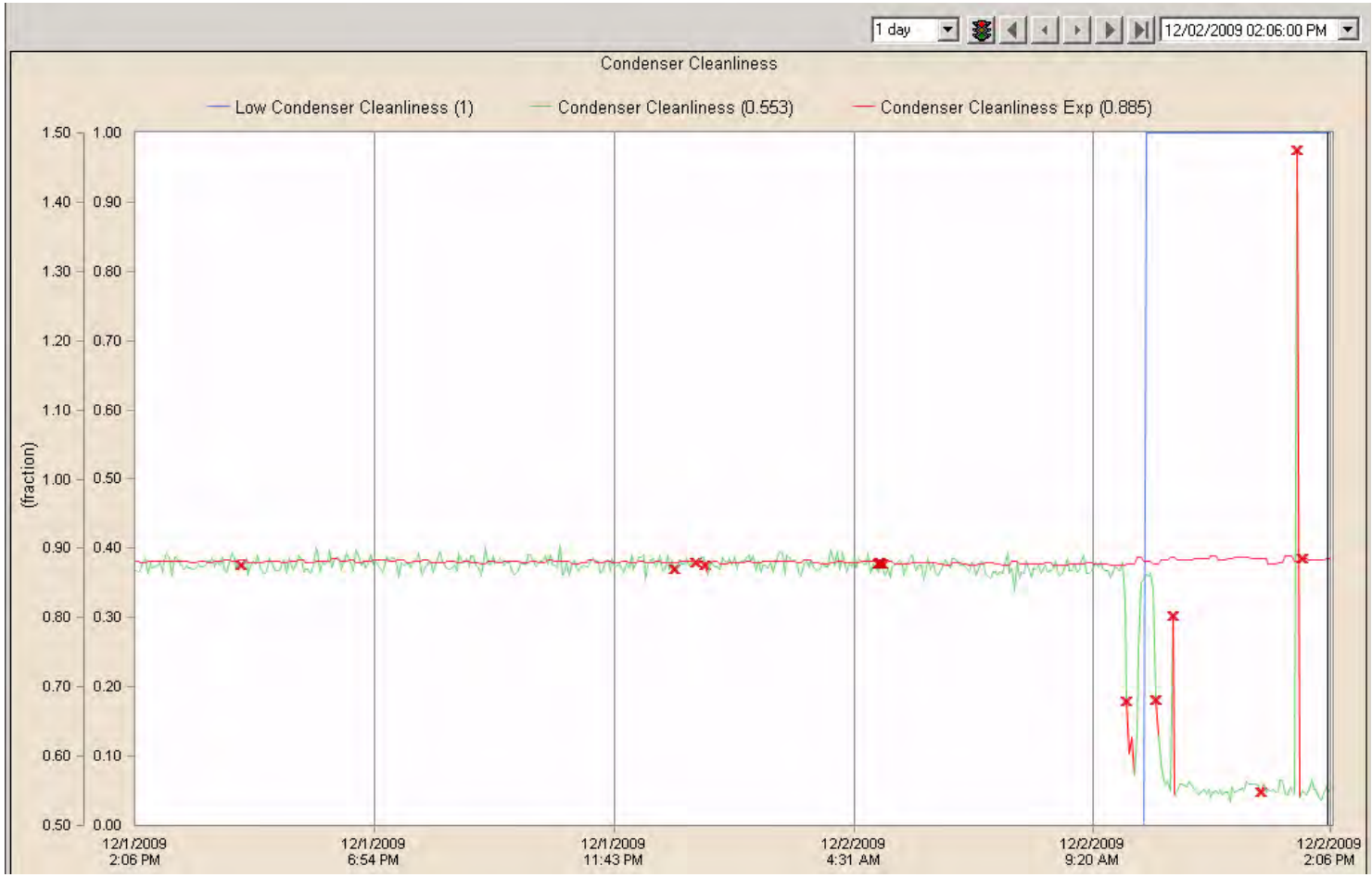
Cleanliness Alert



NeuCo
The Optimization Standard™

Condenser Cleanliness

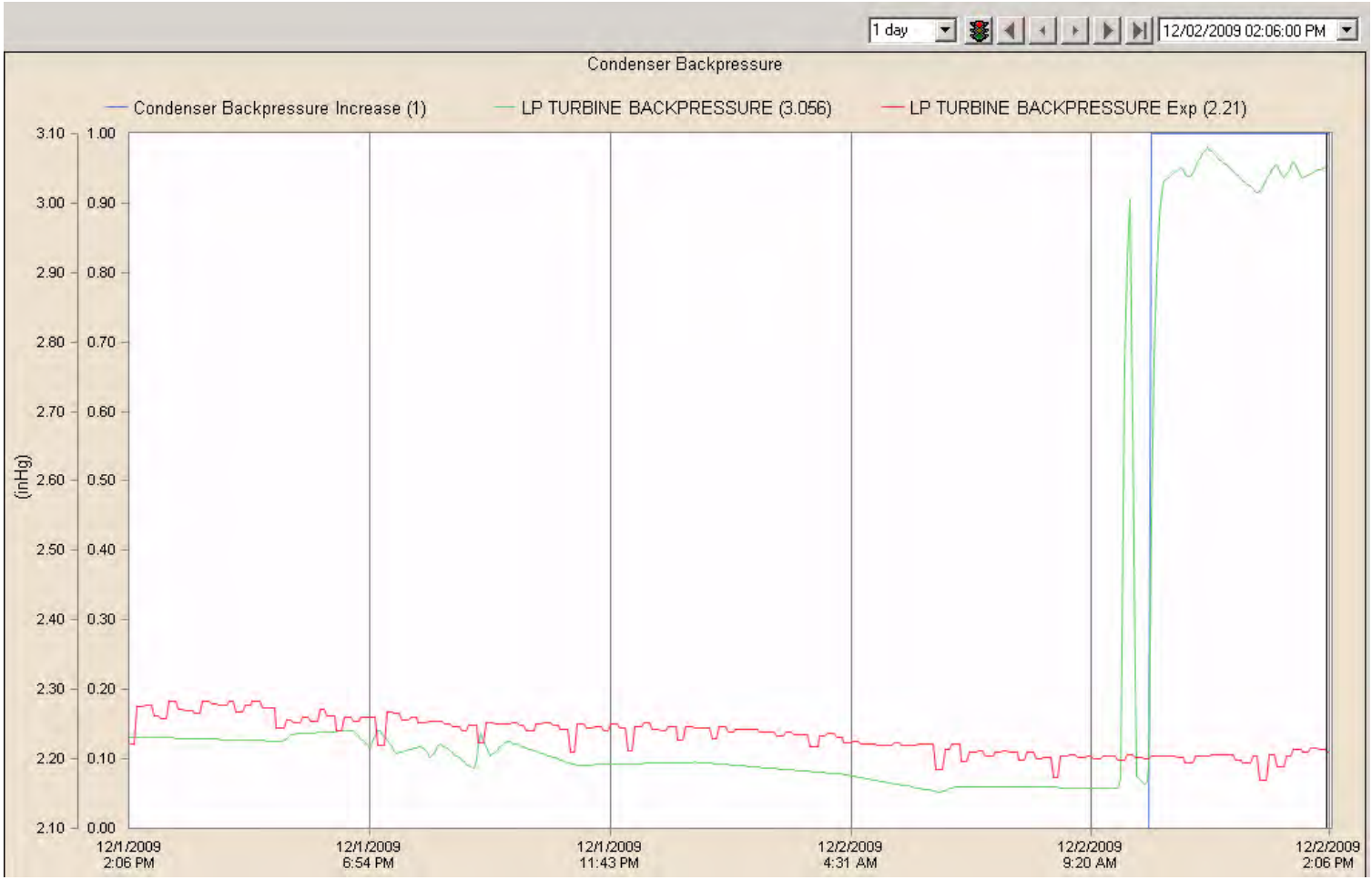
- Condenser Cleanliness significantly changes from expected at around 10 am.



NeuCo
The Optimization Standard™

Condenser Backpressure

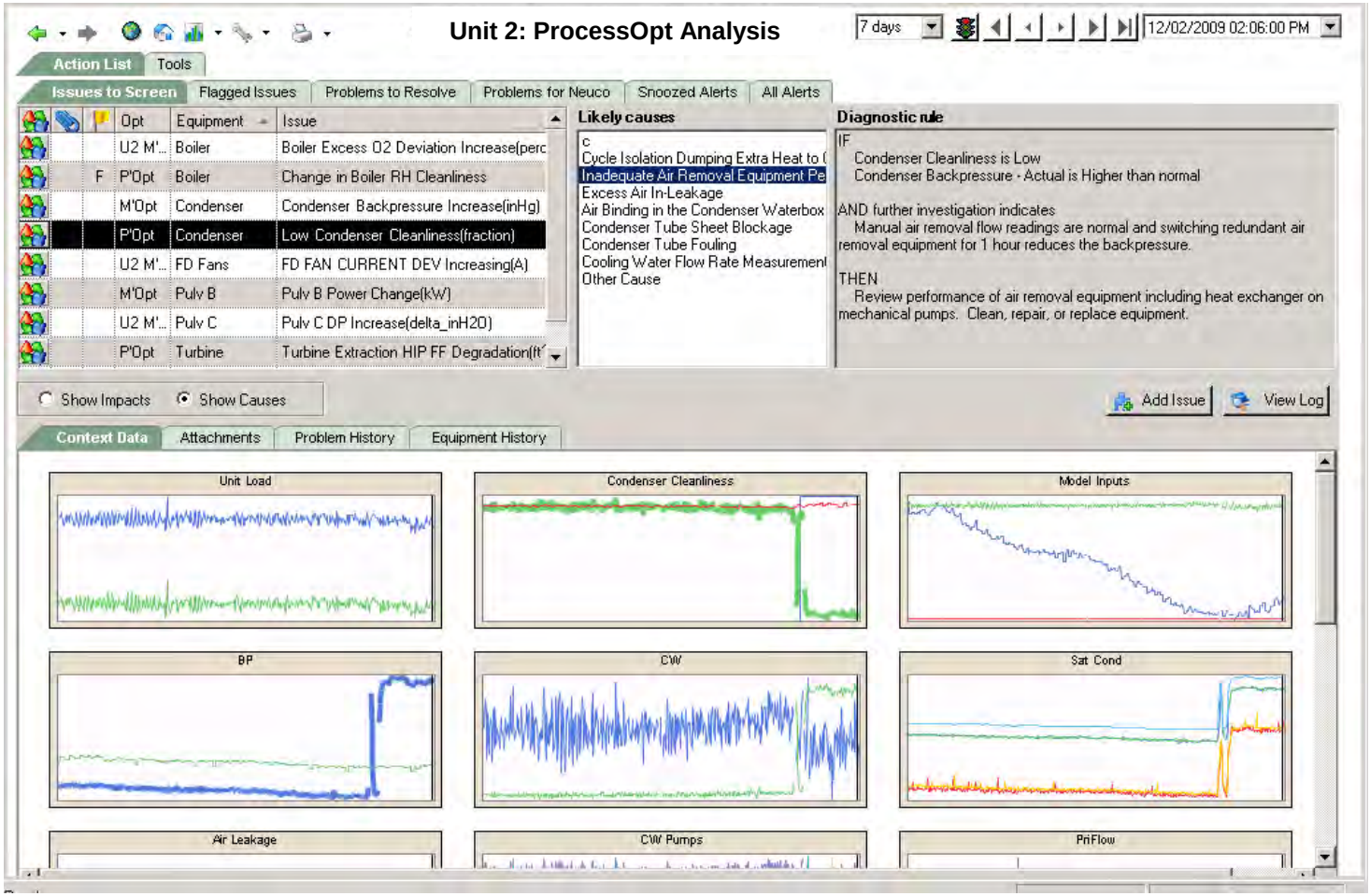
- Condenser backpressure also significantly changes at the same time.



NeuCo
The Optimization Standard™

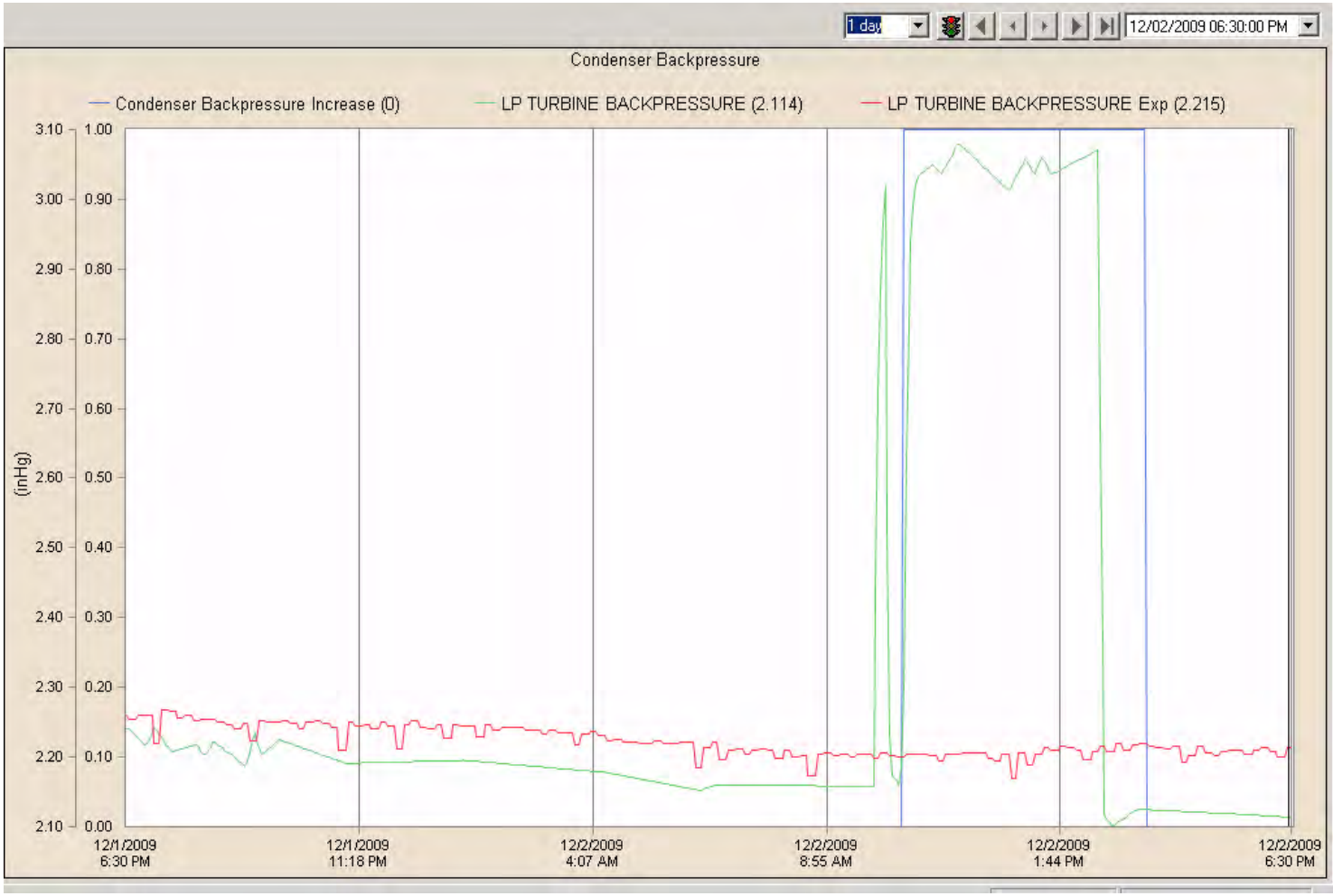
Diagnosis

- Low condenser cleanliness and high condenser backpressure indicates inadequate air removal equipment performance.



Resolution

- Maintenance crew reconnects vacuum pump and performance returns to normal.



NeuCo
The Optimization Standard™

Thanks!

spinney@neuco.net

NeuCo
The Optimization Standard™